Public Assistive Displays: Employing Public Interactive Displays to Improve Public Transport Access 4All

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Figure 1: Current methods for ensuring access on public transport: badges, priority seating and Hidden Disability lanyards versus our proposal: the public and interactive 4All Display, which makes other users aware of the needs of their fellow passengers discreetly.

ABSTRACT

Access to public transport services is vital for ensuring equitable participation in society. Yet, barriers to public transport can be experienced due to the challenge of communicating complex – often personal – needs to co-located passengers and staff in dynamic public transport environments. In this project, we explore the potential of leveraging public interactive displays (PIDs) to improve access to public transport systems. To start, we investigate the eminent access needs of passengers on public transport journeys and establish the importance of communication with co-located passengers as a means for ensuring more positive journey outcomes. Consequently, we build and explore the potential of a PID technology probe called the *4All Display*. Our *4All Display* prototype proactively recognises the contextual needs of its users and employs this data to supportively inform passengers about the needs of their fellow co-located passengers in a discreet and accessible way.

KEYWORDS

Accessible Transport, Public Interactive Displays

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1 INTRODUCTION

In populous and dense urban cities public transport access is vital for participation in society. For London (UK), the city of focus of our paper, the government body responsible for operating its transport network, *Transport for London* (TfL) – reports that 1.35 billion passenger journeys are completed annually [23]. Due to this volume, the diversity of socio-economic background and disability status amongst passengers is great [10, 12]. Consequently, it is essential that transport networks are designed to be accessible for *all* members of the public. However research has continued to identify that public transport is regularly inaccessible for many communities [10], including: pregnant persons [19], people living with disabilities [5], families with young children [7] and people living with health conditions [2]. Critically, access barriers to public transport are often *invisible* – meaning that there is an added and potentially socially debilitating onus for these communities to communicate their needs to co-located transport staff and passengers [6]. At present to mitigate these access challenges, TfL provides marked priority seating on transport services and offers attachable TfL badges to inform others of access needs (see Fig. 1) [13]. Yet, these approaches are not without shortcomings. For instance, priority seating is often occupied by passengers *without access needs* [8, 9, 16, 18, 28], and available badges are often limited to a finite set of needs and lack visibility in crowded environments. Other, more discreet approaches – such as the Hidden Disabilities lanyard [14] still perpetuate stigmas for the wearer.

In this Late-Breaking Work, we consider how we might use public interactive displays as an option for communicating access needs to co-located passengers on transport networks. Through initial user-centred work, we conceptualise, implement and test the *4All Display*. The *4All Display* discreetly informs access needs of individuals within a given transport environment, without necessarily revealing their identity, thereby removing the need for the passenger to communicate their needs directly (e.g., verbal help-seeking), or indirectly (e.g., by wearing a badge). For example, a *4All Display* could make fellow passengers prematurely aware of an on-boarding passenger's challenges with standing for extended periods – meaning priority seats will be freed for the passenger upon arrival. In another context, a 4All Display could be used to make passengers aware of an on-boarding passenger's potential need for extra assistance – such as help loading their child's heavy push-chair into the carriage. Our contribution is three-fold: (1) preliminary interview data on the needs of individuals who require additional accommodation on transport networks; (2) the 4All Display and the related insights from its user-centred design; and (3) findings from a small-scale evaluation of the 4All display, which might inform the design of context-aware displays to support access in public settings.

2 BACKGROUND

2.1 Public Interactive Displays

Public displays are designed to be visible to members of the public who can view simultaneously [17, 21]. They are ubiquitous in modern society; particularly in public spaces in cities, shops and education settings. Public interactive displays (PIDs) extend public displays by facilitating forms of interactive engagement with those located nearby within the environment [20]. Parra et al. [21]'s in-the-wild-study offers useful guidelines for ensuring passers-by notice and interacted with PIDs; considering orientation, content, content format and dynamics and their influence [21]. Much work in HCI has explored PIDs [20], including studies that have investigated their potential for sharing private data [26].

2.2 Public Displays on Public Transport

Developed urban environments are complex and require excellent design, especially in the visual presentation if information, if people are to navigate them. Much work has been done on how we might better present information in digital and non-digital forms in public spaces. Focusing on London alone, there has been much technological innovation to improve passenger experience including next bus countdown timers at stops [15], bus information on TVs [15], and map-style route displays [22]. Outside the context of London, much prior work has explored how public displays might include travel information, social media screens and advanced advertising [3] – establishing the extensive benefits of more personalised public transport displays for ensuring greater support and trust in services [3].

2.3 Public Transport Accessibility

Access to public transport services is enshrined in UK law [11] and vital for ensuring equitable participation in society [6]. At present, TfL offers many services to improve transport accessibility and staff are trained to provide a turn up/go service and guidance concerning accessible routes. The dedicated app which serves TfL (TfL Go) provides real-time guidance of access e.g. providing information about step-free access. Furthermore, on all public transit carriages, TfL provides an allocation of *priority seats* for users that require seating during transit. TfL also offers free badges/cards for those who may have difficulties with requesting a seat during transit from strangers. The currently available badges/cards are, *"Please offer me a seat"* designed for the elderly/non-visible impairments and, *"Baby on Board"* for pregnant women. Despite these efforts, news and research have identified that TfL still presents accessibility challenges for *many* communities. Most stations within the network do not have step-free access for those with mobility issues [25]. Within carriages, previous research [8, 9, 28] has found that people living with disabilities, pregnant persons and older adults still face difficulty accessing a seat and seat requesting. Expectant mothers wearing "Baby on Board" badges can typically wait five stops for a seat [16, 18, 19, 24]. Consequently, TfL delivers announcements and posters urging members of the public to *"look up"* for those that may need a seat [27].

3 DEVELOPMENT OF THE 4ALL DISPLAY

The 4All Display was developed over two complementary sessions. Firstly, preliminary interviews with a broad demographic of public transport users. Immediately followed by a low-fidelity prototyping focus group intent on co-creating the 4All Display. All participant information is outlined in Table 1.

3.1 Preliminary Interviews

Preliminary interviews were conducted with 8 public transport users. Interviews were undertaken to develop an understanding of user's needs and public transport experiences that would shape the development of the 4All Display.

3.1.1 *Research Environment and Data Analysis.*

As with all parts of this study, interviews were conducted within a King's College London activity room and was approved by an King's College London Research Ethics Subcommittee. Each interview lasted ~one hour, transcribed and analysed using Miro. Data was affinity-mapped into categories of participants' experiences. This process supported the low and high-fidelity iterative development of the 4All Display prototype.

3.1.2 *Participants.*

All recruited interviewees (N=8) were TfL public transport users. Collectively, amongst interviewees, the most common mode of transport was the London Underground. The most common purpose for travel was for work. Participants' average age was 26. Participants travelled on average 56 minutes a day, 3.5 days a week. Interviewees had varying needs on public transport from: travelling with small children, to carrying prams/luggage, living with invisible disabilities/debilitating health conditions. One participant was entirely new to using TfL public transport services.

Participant	Weekly travel	Daily commuting time	Gender - Age	Purpose	Uses	Attendance
1	5 days	1 hour	M – 20	University	Train	I, FG, T
2	3 days	30 mins	F – 22	University, Leisure	Tube	I
3	5 days	1 hour 10 minutes	M – 20	University, Work	Train, Tube	I, FG, T
4	2 days	1 hour	F – 29	Work, Leisure	Train, Tube	I
5	2 days	2 hours	F – 41	Work	Train, Tube	I
6	5 days	30 minutes	F – 19	Work, Leisure	Tube	I, FG
7	5 days	15 minutes	F – 20	University	Tube	I, FG, T
8	1 day	1 hour	F – 40	Work	Train, Tube	I
9	6 days	20 minutes	F – 18	University, Leisure	Tube	T

Table 1: Summary of participants throughout design process. Attendance denoted by: *I – Interviewed, FG – Focus Group* and *T – Usability Testing.*

3.1.3 *Interview Procedure.*

Interviews started with introductions and questions regarding weekly travel patterns (i.e., modes of transport/frequency of usage). Interviewees were asked about: positive/negative experiences on public transport, perspectives on current public transport accessibility and suggested changes they would make to the network. We also probed their attitudes to public displays, targeted advertising and communication experiences with strangers on public transport, finalising in a wrap-up and reflection.

3.2 Interview Findings

Qualitative findings established that interviewees had different public transport travel experiences, challenges and needs. Nonetheless, all interviewees expressed the significance of public transport access as it *"opens up the whole city" (P4).* Interviewees expressed the importance of awareness – specifically access barriers concerning insufficient transport seating/space, difficulties with invisible conditions and (un)awareness from strangers. Participant 8 openly reflected on their own lack of awareness, *"sometimes I'm engrossed in a book and then suddenly I look around and go... Oh god, there was somebody that actually needed that seat" (P8).*

Conversely, participant 1 commented on their active monitoring of strangers' needs, *"I'm normally looking out. If anyone pregnant, or if anyone has a small child, or if they're elderly".* Interviewees also commented on the difficulties of interacting with others/objects in an enclosed, confined and stressful dynamic public transport environment. Participant 4 noted, *"If you're a wheelchair user, I don't think there is much space on the tube" (P4).* Another noted the difficulty of communicating with strangers who are often on their phones, *"I once asked [a stranger] for the time but that passenger was annoyed that I had disturbed him" (P3).* Finally, participant 8 recognised the challenge of having a pram as a young mother, *"I couldn't get on the tube with a pram. I think people are very selfish actually!" (P8).* Indeed, participant 5 even admitted that they occasionally resorted to having *"to push people so they can actually have some space on there".*

Finally, interviewees reflected on the unpredictable nature of the public transport environment, potential anxieties and the importance of politeness. Desiring extra space, one participant noted *"it being quite unpredictable to know where are the less busy parts of the train" (P5).* Indeed, this anxiety is heightened if living with a severe allergy – one participant was allergic to coffee. With hot conditions, delays and strikes – interviewees reflected on feeling *"nervous" (P3 and P6)* whilst travelling. However, one interviewee mentioned they were always grateful if, *"people offered them a seat and my needs are being validated" (P6).*

3.3 Focus Group on Low-Fidelity 4All Display Prototyping

With insights gathered from interviews, we sought to explore users perspectives on a PID that interactively communicates the needs of co-located passengers. One week after the interviews, we held a focus group to get insights and iterative feedback on different low-fidelity PID designs.

3.3.1 *Research Environment, Data Analysis and Participants.*

The 1-hour focus group was conducted via videoconference. The focus group was fully recorded and transcribed. Subsequent analysis/dissemination occurred in Miro. All focus group participants (N=4) participated in the preliminary interview process.

3.3.2 *Focus Group Procedure.*

Before the focus group, we prototyped 26 Axure mock-ups of different PID designs drawn from the needs/insights of the affinity mapped preliminary interviews. The low-fidelity PID designs offered support for different communities: pregnant people, hidden disabilities, older adults, deaf and hard of hearing (DHH), mothers with young children and tourists new to London. Consequently, the low-fidelity PID screens raised awareness about differing user needs including: allergens (e.g., nut, coffee), luggage assistance, support with buggies/prams, overcrowding, hydration, injuries and local attractions. The focus group began with informal introductions, then participants were immediately shown the 26 low-fidelity PID designs. Participants were questioned and asked to reflect/share their perspectives. Key lines of questioning probed participants for their perspectives i.e., if they could understand the transmitted message, the readability of the display, the envisaged actions they would take based on the display's information and more general feedback. The PID screens used a mix of symbols, text and both, with a range of typefaces and designs to explore preferences. The PID designs were then collaboratively iterated based on participants' critiques and improvements – this feedback was used to shape the 4All Display prototype.

3.3.3 *Focus Group Insights.*

Collectively, participants expressed strong preference for text-based transmission on PIDs because it

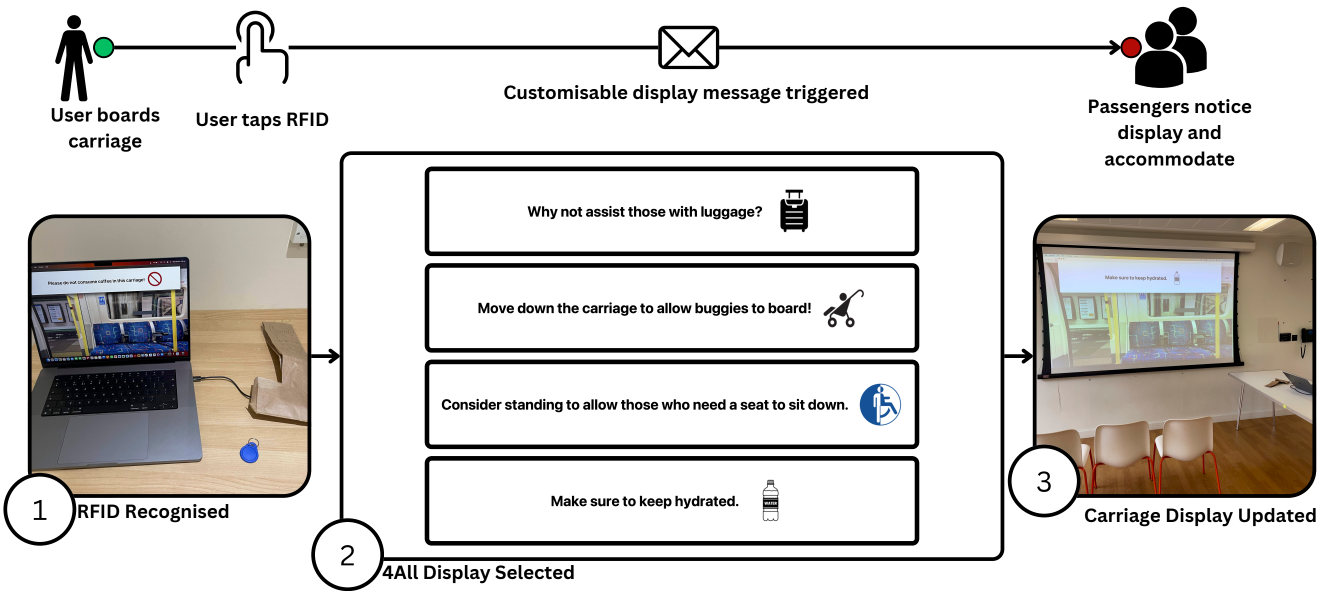

Figure 2: Summary of 4All Display system architecture and envisaged public transport user interaction.

was, *"most clear [and] very readable" (P1)*. Participants mentioned that framing the text message on the 4All Display as *an instruction* would help prompt constructive action, *"I think its fairly straightforward – telling people in the carriage not to consume coffee in the vicinity" (P7)*. In response to generalised PID instructions e.g., *"Be more considerate of others"* – participants were uncertain of the appropriate accommodations to make i.e., *"I don't think its super clear" (P1)*. Further feedback included the importance of bold text, animation and colour for communicating urgency e.g., *"I'm not sure why the second sentence isn't bolded as well, because its fairly important" (P6)*, *"maybe some extra colour" (P1)* and *"I like the idea of it flashing up!" (P1)*. Whilst, shorter messages were preferred *"for those in a rush" (P6)*. With regards to the PIDs use of *just* symbology – participants struggled with accurate recognition of symbols' meaning e.g., in response to a water bottle symbol: *"by looking at the symbol, it could be a bottle of water, bottle of oil or anything like that" (P3)*, *"it looks like spray paint" (P7)* and *"I didn't know what the symbols meant" (P3)*. This aside, participants did suggest that symbols would be important for those in a rush or facing language barriers i.e., *"someone visiting London. They might not be able to understand or read and write in English" (P7)*. On the whole, participants were very positive about the potential of PIDs on public transport – *"I like the idea a lot actually" (P6)*, they felt that a PID would improve their awareness and attention particularly, *"when I'm not paying attention with my headphones in" (P6)*. Overall, participants believed using both symbols and messages would be preferable for all passenger types – this typography is reflected in the 4All Display implementation.

4 THE 4ALL DISPLAY DESIGN

Using insights gathered from the interviews and focus group we prototyped a PID called the 4All Display. In terms of system architecture the 4All Display is composed of two components: (1) hardware that allows passenger's needs to be registered and (2) software that displays message to co-passengers.

4.1 4All Display Prototype Implementation: Hardware and Software

In terms of hardware, the 4All Display receives input concerning co-located users' needs from scanned RFID tags. Users tap an RFID tag containing data relating to their need on a sensor whilst boarding the tube/train carriage, similar to many public transport systems e.g., the TfL Oyster travel card. The hardware involved is a PC running the 4All Display graphical software connected to a stationed Arduino wired to an RFID sensor. Its display was connected to a projector. The 4All Display graphical user interface for the Software was a Python application. Simple instruction sets e.g., *"allergy"* and *"coffee"* were written to the tags for classification. Future implementations might look to develop software so that is adaptive to sensors relevant to the public transport network. Automatic adaptation based on co-located passengers' needs could be done by: continuing to use RFID sensors, using cached needs data from the passengers tapping into the public transport network (i.e., payment/oyster card), leveraging passengers Bluetooth smartphone signals or even camera recognition.

4.2 Integration Into Existing TfL Infrastructure

Currently TfL's tube carriages already contain displays, which are used to display relevant information including: current station, route information and warnings for door closures. These existing

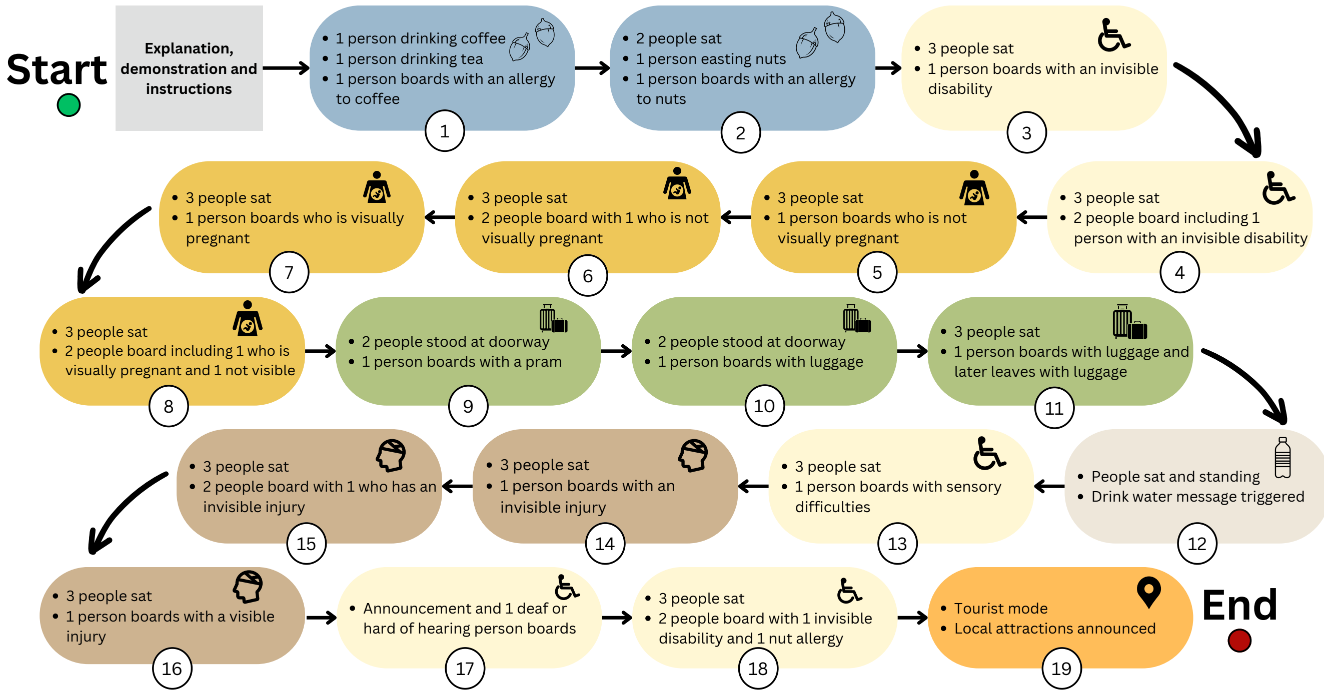

Figure 3: Summary of 19 role-played scenarios with 4All Display – considering different communities including: allergies, invisible disabilities, pregnant persons, heavy objects, hot carriage temperatures, health conditions and tourist guidance.

displays could be integrated/programmed to dynamically display the relevant 4All Display text/information. Furthermore, the displays could be further improved to include relevant customisation regarding colours, symbols and formatting. In terms of user access, TfL employs a contactless system whereby users tap into the underground network at the start and end of their journeys using a travel card. In light of this, the 4All Display could be integrated whereby users tap their travel card pre-programmed with relevant information relating to their need. Upon boarding the carriage, the display will dynamically update to their currently programmed need. Further extensions of this system, could allow users to customise their displayed needs whilst boarding via their TfL account/TfL Go app.

5 EVALUATION OF THE 4ALL DISPLAY

We implemented a final high-fidelity version of the 4All Display to be tested in a group usability study involving role-playing with 4 participants. We sought to understand how the 4All Display would be experienced in a simulated public transport environment by commuters, and to understand passengers' reactions to the public display's instructions and unpack their perspectives.

5.1 Research Environment, Data Analysis and Participants

The usability testing was conducted in a university usability lab and lasted ~1.5 hours. We aimed to approximate a typical passenger environment – we arranged seating, and employed a projector screen with overlapped photography i.e., Figure 2, placing the prototype to most effectively simulate a tube carriage. Signage was employed to indicate where participants could scan their RFID tags. The RFID tags were already encoded with the relevant data concerning users' personalised needs. After all role-play scenarios had been completed, participants were interviewed. The study and the interview were recorded, transcribed, then analysed using Miro. We completed the group user study with participants (N=4) role-playing different scenarios of usage with the 4All Display.

5.2 4All Display Evaluation Procedure

To determine the efficacy of the 4All Display in simulated 'real world' scenarios, we asked our participants to roleplay different contexts of usage and interaction. For each scenario, participants were allocated different roles. The 19 scenarios are outlined in Figure 3 and each scenario took about 2-5 minutes to complete. To begin a scenario, a randomly assigned participant would board the carriage whilst scanning their RFID tag triggering the 4All Display to display a new message e.g., "*Why not assist those with luggage*". Thereby the 4All Display communicated the needs of on-boarding passengers to the co-located participants, role-playing as fellow passengers. Following this, the remaining 3 participants freely self-organised and decided upon appropriate actions in response to the 4All Display's carriage message. We captured data about how long it took for participants to react/respond to the message, and also ranked whether the participants made 'desirable' changes to their behaviour (e.g., moving for someone with mobility challenges). After each scenario, participants were asked to note down what they believed the display was communicating, what action they took, and the reasoning for that action. Once all the scenarios had been completed, participants performed an exit interview with questions relating to comfort, awareness of others and suggested improvements to the 4All Display.

5.3 Results from 4All Display Evaluation

5.3.1 Quantitative Results. Overall, there was a 84% success rate i.e., in 16/19 4All Display scenarios participants reacted 'desirably' – changing their behaviour appropriately based on the output of the 4All Display. The average participant time to change behaviour was 9 seconds. On the three occasions, the 4All Display was unsuccessful as participants misunderstood its message.

5.3.2 Qualitative Findings from the Exit Interview. Participants were enthusiastic about the 4All Display prototype and mentioned that if the product was deployed on public transport it would *"help identify those that may need more support when travelling (P1)"*. In addition, all participants felt comfortable with the 4All Display's presence and believed the display would probably help them to *"likely pay more attention (P7)"* to their surroundings and assist fellow passengers. In terms of feedback, participants suggested several improvements to the 4All Display, in particular regarding the symbols displayed. They noted that integration into TfL's existing symbol standard would improve recognition and familiarity. One participant suggested that additional voice announcements that reinforced the 4All Display's message transmission would improve collective accessibility. Notably, the 4All Display's generic messaging e.g., requesting passengers *"to be more considerate of others"* did cause some participant confusion as participants were unsure how to most appropriately act to accommodate co-located people's needs. One participant also suggested that the 4All Display's messages could be even more discreet and direct just mentioning *"not to consume food or drink (P9)"* without mentioning the underlying user need of allergies.

6 DISCUSSION AND FUTURE WORK

Public displays situated within public transport will invariably have a myriad of different users [1]. Here, we have highlighted the potential for PIDs to accommodate and support the needs of TfL users discreetly and accessibly. Further work should explore different display options and preferences for more communities. Albeit emphasised in prior PID work by Parker et al. [20], core to the success of such personal information being highlighted in public is privacy. Indeed, when displays are in public settings, close management will be key to ensure they fulfil genuine needs, do not violate trust and preserve passenger anonymity. Although an advantage of the 4All Display is that it does *not* directly identify the user with underlying access needs. We must continue to take inspiration from Bennett et al. [4], where the assistive technology encourages *interdependent* relations; that is, with a more collective view on access situated within the environment.

Participants envisioned many positive improvements to our prototype. Additional recognition modalities e.g., through environmental sensors might improve the messages presented to passengers. Presently there is no 'exit' state to the system; the display continues until a new update via RFID is provided. Determining whether the display is still required is also a complex challenge, likely involving more sensing (with possible privacy concerns). Future versions of the 4All Display might also adapt based on attuned environmental sensors and offer helpful suggestions to co-located passengers, such as hydration during high summer temperatures within the transport network. Turning to output modalities, participants expressed the potential for including an audible complement to the visual display – this would be useful for users with visual impairments, but also important for those whom are not visually attending (e.g. looking at their phones, reading). In terms of limitations, this research is scoped by a small and finite set of users. Whilst these users did have diverse needs and were useful for initial ideation/evaluation of the 4All Display, a more diverse set of users – especially users with complex physical or cognitive challenges – should be considered in future work. Finally, our usability study was conducted in a lab. In reality, the complexity of a dynamic transport environment might affect our results – especially the users' adherence and comprehension of the 4All Display.

7 LIMITATIONS

This research has several limitations. By using a lab environment, we abstract from the many complexities of a live transport system such as: the moving carriage environment, constant influx of passengers and sudden loud noises. Equally, performing testing in a simulated environment over a small sample size would make it challenging to generalise these findings for a broader population. Instead, short to medium-term field-deployment of the display in real-world settings would provide more established findings. Future studies should also consider *more* direct research with participants living with different disabilities and focus on the 4All Display's performance for their specific needs. Albeit, the 4All Display has been shown to be adaptive to different needs – offering wide application.

8 CONCLUSION

To conclude, we have designed and built a 4All Display prototype – a new class of PID which acts as an assistive technology thereby recognising the contextual needs of its users and leveraging this data to supportively inform co-located passengers in a discreet and accessible way. Our interviews and focus groups informed a final prototype which enables a new, discreet and environment-centric way of supporting users who might require further accommodations in busy public transport environments. We hope that the initial work presented can inspire: (1) designers of public displays and public environments to consider how we might support accessibility and those living with diverse needs, and (2) assistive technology developers, who might leverage public displays to support communication – situating assistance within the environment, rather than as a responsibility of the individual.

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A APPENDIX

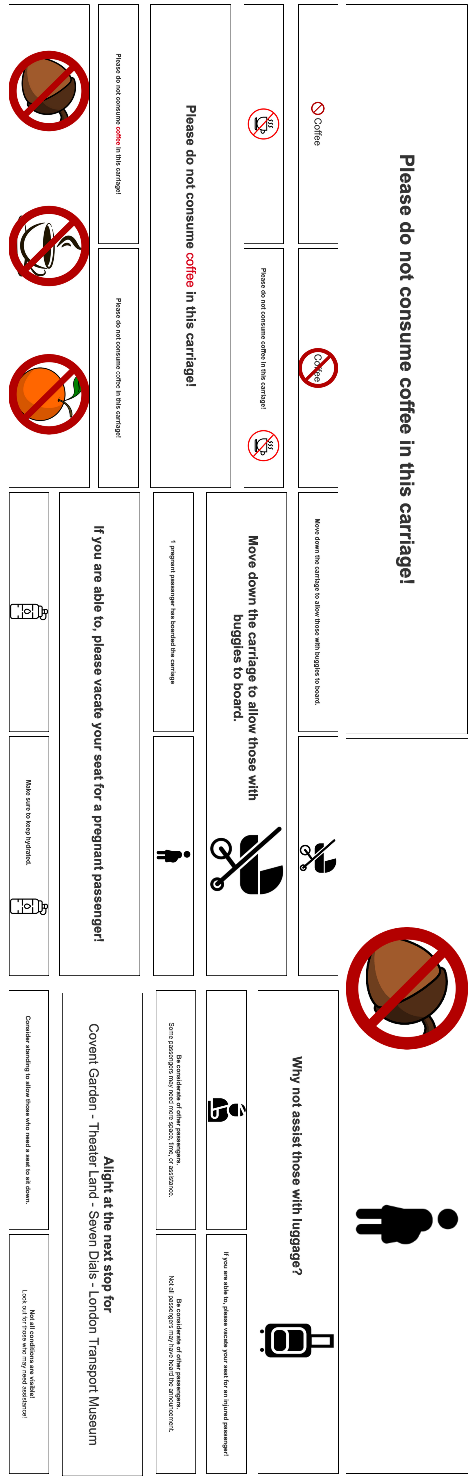

Figure 4: 26 public interactive displays used during low-fidelity prototyping focus group.